

Appendix C
PCB Food Web Model
Kalamazoo River Superfund Site

Table C-1
Input Parameters for PCB Food Web Model
API/PC/KR

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Receptor	Total PCB Conc ¹ (ABSAs 3-10) (ppm)	Method	Primary Exposure Media	Mean BCF/BAF	Home Range (hectares)	Site Foraging Frequency (SFF) ²	Dietary Fraction (DF)	PCB Conc Diet (ww food, dw SED/FPSED, mg/kg)	Ingestion Rate IR _{ww} (kg/d) NIR _{ww} (kg/kg-d) IR _{dw} (kg/kg-d)	Body Weight BW (kg)	DOSE (Sum (NIR _{ww} * PCB Conc food item * DF food item) + (NIR _{dw} * U95 PCB Conc SED or FPSED * DF SED or FPSED) mg/kg-d)	LOAEC (conc) or LOAEL (dose) (exposure duration) Species –Effect – Reference	Criteria, Threshold, or NOAEC (conc) or NOAEL (dose)
SW (range of U95) (mean of U95)	0.000016 - 0.000108 0.000043	Measured	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.000014 mg PCB/L - EPA 1980 (protection of piscivorous wildlife, dietary exposure)
SED (range of U95) (mean of U95)	0.30-13.6 7.3	Measured	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	19.5 mg PCB/kg carbon - EPA 1988b (protection of piscivorous wildlife, dietary exposure)
FP SED/SS (range of U95) (mean of U95)	11.7 - 16.2 14.6	Measured (ABSAs 5, 7, 8)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	see SED see SS
SS (TBSA) (range of U95) (mean of U95)	0.23-30.2 16.9	Measured (TBSAs 3, 5, 10, 11)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Species-specific LOAEC/(SUM (BAF*DF)SFF) - Boucher 1990
Algae (range of U95) (mean of U95)	0.016-0.108 0.043	Estimated (U95 PCB Conc SW *BCF)	SW	1,000 (Diatom, Keil, et al. 1971 in EPA 1980)	NA	NA	NA	NA	NA	NA	NA	0.0001 mg/L Algae (diatoms) -Delayed and Reduced Growth - Fisher and Wurster 1973 in EPA 1980	None
Aquatic Macrophyte (range of U95) (mean of U95)	0.05 – 2.5 1.3	Estimated (U95 PCB Conc SED*BCF)	FP SED/SS	0.182 (<i>Hydrilla</i> , mean of n=2 (Hopple and Foster 1996) assume 87% water content (EPA 1993),	NA	NA	NA	NA	NA	NA	NA	No Available Data	None
Terrestrial Macrophyte (range) (mean)	<0.04325 – 0.0692 0.023	Measured (n = 8)	FP SED/SS	0.037 (U95 of onsite garden plot data, 0.0008 (mean of tomato BAF (rep. fruit) (CDM 2000)	NA	NA	NA	NA	NA	NA	NA	No Available Data	None
Aquatic Invertebrate (Water Column) (range of U95) (mean of U95)	0.058-0.39 0.16	Estimated (U95 PCB Conc SW *BCF)	SW SED	3,650 - geo mean of mosquito and cladoceran (Mayer, et al. 1977 in EPA 1980)	NA	NA	NA	NA	NA	NA	NA	0.0008 mg/L Midge Larva - Nebeker and Puglisi 1974 in EPA 1980	None

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Receptor	Total PCB Conc ¹ (ABSAs 3-10) (ppm)	Method	Primary Exposure Media	Mean BCF/BAF	Home Range (hectares)	Site Foraging Frequency (SFF) ²	Dietary Fraction (DF)	PCB Conc Diet (ww food, dw SED/FPSED, mg/kg)	Ingestion Rate IR _{ww} (kg/d) NIR _{ww} (kg/kg-d) IR _{dw} (kg/kg-d)	Body Weight BW (kg)	DOSE (Sum (NIR _{ww} * PCB Conc food item * DF food item) + (NIR _{dw} * U95 PCB Conc SED or FPSED * DF SED or FPSED) mg/kg-d)	LOAEC (conc) or LOAEL (dose) (exposure duration) Species –Effect – Reference	Criteria, Threshold, or NOAEC (conc) or NOAEL (dose)
Aquatic Invertebrate (Benthic) (range of U95) (mean of U95) (crayfish)	0.46-3.1 1.2 0.0323	Estimated (U95 PCB Conc SW *BCF)	SW SED	28,900 - geo mean of <i>Gammarus</i> , n = 3 (Nebeker and Puglisi 1974 in EPA 1980) 750 – crayfish (Meyer et al. 1977)	NA	NA	NA	NA	NA	NA	NA	0.0008 mg/L Nebeker and Puglisi 1974 in EPA 1980	None
Earthworm (range of max) (mean of max)	0.025-3.2 1.5	Measured (Max PCB Conc, depurated carcass)	SS FP SED/SS	0.09 (depurated worms)	NA	NA	NA	NA	NA	NA	NA	No Available Data	None
Sucker (range of U95) (mean of U95)	0.49-2.8 1.7	Measured (U95 PCB Conc, WB)	SW SED	83,000 (calculated SW)	NA	NA	NA	NA	NA	NA	NA	0.0002 mg/L Fathead Minnow - Defoe, et al. 1978 in EPA 1980	None
Carp (range of U95) (mean of U95)	9.0-19.1 12.1	Measured (U95 PCB Conc, WB)	SW SED	583,000 (calculated SW)	NA	NA	NA	NA	NA	NA	NA	0.0002 mg/L Fathead Minnow - Defoe, et al. 1978 in EPA 1980	None
SM Bass (range of U95) (mean of U95)	1.8-8.7 5.4	Measured (U95 PCB Conc, WB)	SW Prey	249,000 (calculated SW)	NA	NA	NA	NA	NA	NA	NA	0.0004 mg/L Largemouth Bass - Acute LC ₅₀ (2.3 µg/L)/geo mean ACR for FW Fish (6.4) - Birge, et al. 1979 in EPA 1980	None
Fish (mean of mean of U95, 3 species)	6.4	Measured (U95 PCB Conc, WB)	SW Prey	305,000 (mean, 3 species)									
Muskrat (range of max) (mean of max)	0.21-2.9 1.2	Measured (Max PCB Conc ww, WB)	SED FP SED/SS Vegetation	0.08 Whole body (mean of max PCB conc / mean of U95 FPSED)	0.13 EPA 1993	1.0	Semi-Aquatic Plants 1.0 (based on mean <i>Hydrilla</i> BAF, 0.182) SED 0.094 (raccoon) EPA 1993	1.3 7.3	0.42 0.3 0.037 EPA 1993	1.4 EPA 1993	0.417	100 mg/kg FW diet (240 days) - 5 mg/kg-d per Burse, et al. 1974 in EPA 1980) - Rat – Substantial Weight Loss - Kimbroughj, et al. 1972 in EPA 1980	33 mg/kg FW diet - 1.7 mg/kg-d (based on LOAEC/3 = NOAEC)

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Receptor	Total PCB Conc ¹ (ABSAs 3-10) (ppm)	Method	Primary Exposure Media	Mean BCF/BAF	Home Range (hectares)	Site Foraging Frequency (SFF) ²	Dietary Fraction (DF)	PCB Conc Diet (ww food, dw SED/FPSED, mg/kg)	Ingestion Rate IR _{ww} (kg/d) NIR _{ww} (kg/kg-d) IR _{dw} (kg/kg-d)	Body Weight BW (kg)	DOSE (Sum (NIR _{ww} * PCB Conc food item * DF food item) + (NIR _{dw} * U95 PCB Conc SED or FPSED * DF SED or FPSED) mg/kg-d)	LOAEC (conc) or LOAEL (dose) (exposure duration) Species -Effect - Reference	Criteria, Threshold, or NOAEC (conc) or NOAEL (dose)
Mink (range of max) (mean of max)	2.6-5.6 3.8	Measured (Max PCB Conc ww, WB)	Prey	Not Applicable because of unknown contribution from multiple exposure pathways	14.1 EPA 1993	1.0	Fish 0.850 Mammal 0.10 Bird 0.05 SED 0.0 (est. from raccoon) Based diet modified from Michigan river (year-round) of Alexander 1977 in EPA 1993). Mammal = 5% mouse and 5% muskrat	6.4 0.79 76.64	0.218 0.18 Heaton, et al. 1995 (LOAEL treatment) 0.08 EPA 1993	1.2 Calculated from Heaton, et al. 1995 (LOAEL treatment)	1.70	0.60 mg/kg FW diet (low effect, EC ₂₅ , see text) - (0.11 mg/kg-d) Mink - Kit body wt. and no. of live kits/mated female, multi-generational, Aroclor 1254, multiple studies - see Appendix D	0.5 mg/kg FW diet (EC ₁₀ , see text) - (0.091 mg/kg-d) - Mink - estimated from low effect (EC ₂₅), see Appendix D
Mouse (range of max) (mean of max)	0.28-0.45 0.37	Measured (Max PCB Conc, WB)	Vegetation and Prey	0.025 Whole body (mean of max PCB conc / mean of U95 FPSED)	0.06 EPA 1993	1.0	Terr. plants 0.44 Terr. inverts 0.56 FPSED 0.02 EPA 1993	0.54 (all tissues) 1.314 14.6	0.0055 0.262 0.0035 EPA 1993	0.021 EPA 1993	0.311	10 mg/kg FW diet (540 days) - 1.35 mg/kg-d, NIR = 0.135 kg/kg-d - White-footed Mouse - Reduced no. of young - Linzey 1987 and 1988)	3.3 mg/kg FW diet - 0.45 mg/kg-d (based on LOAEC/3 = NOAEC)
Robin (mean)	76.64	Estimated for whole body carcass (see Appendix C-2-A for equations)	Vegetation and Invert Prey	93 - mean diet to carcass BAF for alewife to gull (Braune and Norstrom 1989)	0.48 EPA 1993	1.0	Terr. Plants 0.49 Terr. linverts 0.51 FPSED 0.1 EPA 1993	0.012 (fruit only) 1.314 14.6	0.069 0.896 0.016 EPA 1993	0.077 EPA 1993	0.904	0.5 mg/kg-d, ED ₂₅ for egg hatchability in chicken, Aroclor 1248 (Scott 1977 and Lillie 1975, see Appendix D)	0.4 mg/kg-d, ED ₁₀ for egg hatchability in chicken, Aroclor 1248 (Lillie et al. 1974 and Cecil et al. 1974, see Appendix D)
GH Owl	Not Determined	NA	Prey	Not Determined	329 Peterson 1979 in Johnsgard 1988	1.0	Birds 0.47 Mammals 0.53 FPSED 0.02 Craighead and Craighead 1956 (4% aq.inverts dist. equally to birds and mammals) Mammals based on average of mouse and muskrat	76.64 0.79 14.6	0.084 0.056 Craighead and Craighead 1956 0.073 EPA 1993	1.505 Mean of male and female geo mean BW, Craighead and Craighead 1956	2.06	estimated 9.0 mg/kg FW diet, 1.2 mg/kg-d (estimated by NOAEL*3)	3.0 mg/kg FW diet (0.41 mg/kg-d, NIR = 0.138 kg/kg-d, from Sample, et al. 1996) - Screech Owl - McLane and Hughes 1980

Acronyms, Footnotes, and Assumptions

ACRONYMS

WB	Whole Body
BCF/BAF	Whole Body Concentration Biota / Concentration Exposure Medium
LOAEC(L)	Lowest observed adverse effect concentration (level)
NOAEC(L)	No observed adverse effect concentration (level)
SW	Surface Water
SED	Streambed Sediment
FP SED/SS	Floodplain Sediment/Surface Soil
SS	Surface Soil from TBSAs
FW	Fresh Weight
ACR	Acute to Chronic Ratio
*	Value based on half the analytical detection limit (< detection limit value)
NIR	Normalized ingestion rate (IR/BW) – from EPA 1993 unless indicated otherwise
ED ₂₅ or EC ₂₅	Effective dose (mg/kg-d) or concentration (mg/kg), low effect is 0.75 of control response a toxicological endpoint (EC ₂₅ , which represents a 25% decrease in response)
ED ₁₀ or EC ₁₀	Effective dose (mg/kg-d) or concentration (mg/kg), no effect is equal to 0.90 of the control response (EC ₁₀ , which represents a 10% decrease in response)

FOOTNOTES

1. Estimated PCB concentration for Biota = (Conc SW * BCF) or (Conc SED or SS * BAF).
2. SFF = Site Area 518,000 hectares / Home Range

ASSUMPTIONS (see footnotes in Appendix C-2 for additional assumptions)

- Earthworms are conservative and appropriate representatives for terrestrial invertebrate prey (depurated worm data used with soil intake to account for whole body burden)
- Consumers of fish ingest equal amounts of forage, rough, and game fish (represented by sucker, carp, smallmouth bass)
- Whole body PCB concentrations for HERPS (reptiles and amphibians) consumed as prey based on mean SED-to-Frog BSAF (0.23) from Unnamed Tributary, NY (CDM 2001)
- Birds most representative of species consumed by predators are omnivorous passerine birds, represented by American robin
- Bird PCB Conc (whole body) based on diet-to-carcass BAF of 93, from Braune and Norstrom 1989 (alewife to gull BAF)

Table C-2-A. Terrestrial Risk Estimates and PRG Derivation

Floodplain Sediment/Soil-based Exposures

Receptor	BW kg	IR _{ww} kg/d	NIR _{ww} kg/kgbw-d	IR _{dw} kg/d	NIR _{dw} kg/kgbw-d	Soil PCB mg/kg	DF _{soil} fraction	Worm BAF ww/dw	Worm PCB mg/kg
Robin	0.077	0.069	0.89	0.0160	0.2074	14.6	0.1	0.09	1.314
Mouse	0.021	0.0055	0.27	0.0035	0.1647	14.6	0.02	0.09	1.314
Red Fox	4.7	0.752	0.16	0.2452	0.0522	14.6	0.028	0.09	1.314
GH Owl	1.505	0.084	0.056	0.0733	0.0487	14.6	0.02	-	-

DF _{worm} fraction	Veg BAF ww/dw	Veg PCB mg/kg	DF _{veg} fraction	DF _{Herp} fraction	HerpBAF ww/dw	HerpPCB mg/kg	DF _{Bird} fraction	BirdBAF ww/dw	BirdPCB mg/kg
0.51	0.0008	0.01168	0.49	0	-	-	0	-	-
0.56	0.037	0.5402	0.44	0	-	-	0	-	-
0.04	0.0008	0.01168	0.11	0.08	0.23	3.358	0.19	5.25	76.7
0	-	-	0	0	-	-	0.47	5.25	76.7

DF _{Mammal} fraction	MammalBAF ww/dw	MammalPCB mg/kg	Dose mg/kg-d	LOAEL mg/kg-d	LOAEL HQ ratio	NOAEL mg/kg-d	NOAEL HQ ratio	LOAEL PRG mg/kg	NOAEL PRG mg/kg
0	-	-	0.9044	0.5	1.81	0.4	2.26	8.07	6.46
0	-	-	0.3109	1.35	0.23	0.45	0.69	63.39	21.13
0.58	0.0530	0.79	2.4764	5	0.50	1	2.48	29.50	5.90
0.53	0.0530	0.79	2.0551	1.2	1.71	0.41	5.01	8.53	2.91

Soil PCB = mean of U95 values for FPSED measured in ABSAs 5,7, and 8

DF_{soil} = from EPA 1993 or estimated

VegBAF = U95 BAF, all plant species and tissues (0.037) or fruit BAF, from soil-to-tomato BAF (0.0008) (CDM 2000)

Robin NIR_{ww} - Skorupa and Hothem 1985 in USEPA 1993, 11.5 % animal prey, remainder fruit and vegetation

Mouse NIR_{ww} - mean of 6 adult values in USEPA 1993

IR_{dw} (passerine) = (((BW * 1000)^{0.85}) * 0.398)/1000 (USEPA 1993 equation 3-4)

IR_{dw} (rodents) = (((BW * 1000)^{0.564}) * 0.621)/1000 (USEPA 1993 equation 3-8)

IR_{dw} (fox-mammal) = (((BW * 1000)^{0.822}) * 0.235)/1000 (USEPA 1993 equation 3-7)

IR_{dw} (non-passerine) = (((BW * 1000)^{0.751}) * 0.301)/1000 (USEPA 1993 equation 3-5)

(Receptor) PCB = Soil PCB * (Receptor) BAF

HerpBAF = mean of green frog and leopard frog sediment-to-whole body PCB conc, Un-named Tributary, New York (CDM 2000)

MammalBAF = mean of muskrat and mouse BAF, where BAF = mean of max whole body PCB conc / mean of U95 FPSED/soil PCB conc

BirdBAF = est.bird whole body (WB) PCB conc (carcass) / soil PCB conc

Robin Dietary PCB Conc (mg/kg) = dose (mg/kg_{bw-d}) / (NIR_{ww} (mg food_{ww}/kg_{bw-d}) + NIR_{dw} (mg soil_{dw}/kg_{bw-d}))

Robin Dietary PCB Conc (0.824 mg/kg) = 0.9044 mg/kgbw-d / (0.89 mg foodww /kgbw-d + 0.2074 mg soildw/kgbw-d)

BirdPCB = Robin dietary PCB Conc (mg/kg) * diet to carcass BAF for birds (93, alewife to gull, Braune and Norstrom 1989)

BirdPCB (76.7 mg PCB/kg bird) = Robin dietary PCB Conc (0.824 mg/kg) * 93

Soil-to-bird BAF = BirdPCB / Soil PCB Conc = 76.7 mg PCB/kg bird / 14.6 mg PCB/kg soil

Dose = SUM (NIRww * PCBPrey1...x * DFPrey1...x) + (NIRdw * PCBSoil * DFSoil)

Dose (Example = Robin) = (NIRww * Worm PCB * DFworm) + (NIRww * Veg PCB * DFveg) + (NIRdw * Soil PCB * DFsoil)

HQ = Dose / LOAEL or NOAEL

PRG = LOAEL or NOAEL / SUM ((NIRww * BAFPrey1...x * DFPrey1...x) + (NIRdw * DFSED)) = LOAEL or NOAEL / DOSE * SED PCB CONC

PRG (Example = Robin) = LOAEL or NOAEL / ((NIRww * Worm BAF * DFworm) + (NIRww * Veg BAF * DFveg) + (NIRdw * DFsoil))

Table C-2-B. Semi-Aquatic Risk Estimates and PRG Derivation

Instream Sediment-based Exposures

Receptor	BW kg	IR _{ww} kg/d	NIR _{ww} kg/kgbw-d	IR _{dw} kg/d	NIR _{dw} kg/kgbw-d	SED PCB mg/kg	DFSED fraction	FishBAF ww/dw	Fish PCB mg/kg	DFFish fraction
Muskrat	1.4	0.42	0.300	0.037	0.026	7.3	0.094	-	-	0
Bald Eagle	3.75	0.45	0.120	0.145	0.039	7.3	0	0.877	6.4	0.77
Mink	1.2	0.218	0.182	0.080	0.067	7.3	0	0.877	6.4	0.85

Veg BAF ww/dw	Veg PCB mg/kg	DFveg fraction	DFBird fraction	BirdBAF ww/dw	BirdPCB mg/kg	DFMammal fraction	MammalBAF ww/dw	MammalPCB mg/kg	Dose mg/kg-d	LOAEL mg/kg-d
0.182	1.3286	1	0	-	-	0	-	-	0.4167	5
-	-	-	0.17	10.5	76.64	0.06	0.108	0.79	2.1606	0.5
-	-	0	0.05	10.5	76.64	0.10	0.108	0.79	1.6988	0.11

LOAEL HQ ratio	NOAEL mg/kg-d	NOAEL HQ ratio	LOAEL PRG mg/kg	NOAEL PRG mg/kg
0.08	1.7	0.25	87.60	29.78
4.32	0.4	5.40	1.69	1.35
15.44	0.055	30.89	-	-

SED PCB (instream) = mean of U95 values for instream SED (7.3) measured in ABSAs 3-10

SW PCB (instream) = mean of U95 values (0.000043 mg/L) measured in ABSAs 3-10

DFSED = from EPA 1993 or estimated

VegBAF (muskrat) = mean BAF, *Hydrilla*, (from dw/dw BAF of 1.5, fraction moisture = 0.87, Hopple and Foster 1996)

Mouse NIR_{ww} - mean of 6 adult values in USEPA 1993

IR_{dw} (muskrat/mouse - rodents) = (((BW * 1000)^{0.564}) * 0.621)/1000 (USEPA 1993 equation 3-8)

IR_{dw} (mink-mammal) = (((BW * 1000)^{0.822}) * 0.235)/1000 (USEPA 1993 equation 3-7)

IR_{dw} (bald eagle - non-passerine) = (((BW * 1000)^{0.751}) * 0.301)/1000 (USEPA 1993 equation 3-5)

(Receptor) PCB = Soil PCB * (Receptor) BAF

MammalBAF = mean of mean MuskratBAF and MouseBAF, where BAF = max whole body PCB conc / mean of U95 SED PCB conc

BirdBAF = est.bird whole body (WB) PCB conc (carcass) / soil PCB conc

BirdPCB = Robin dietary PCB Conc (mg/kg) * diet to carcass BAF for birds (93, alewife to gull, Braune and Norstrom 1989)

Robin Dietary PCB Conc (mg/kg) = dose (mg/kg_{bw-d}) / (NIR_{ww} (mg food_{ww}/kg_{bw-d}) + NIR_{dw} (mg soil_{dw}/kg_{bw-d}))

Robin Dietary PCB Conc (0.824 mg/kg) = 0.9044 mg/kgbw-d / (0.89 mg food_{ww}/kgbw-d + 0.2074 mg soil_{dw}/kgbw-d)

Dose = SUM (NIR_{ww} * PCBPrey1...x * DFPrey1...x) + (NIR_{dw} * PCBSED * DFSED)

HQ = Dose / LOAEL or NOAEL

PRG = LOAEL or NOAEL / SUM ((NIR_{ww} * BAFPrey1...x * DFPrey1...x) + (NIR_{dw} * DFSED)) = LOAEL or NOAEL / DOSE * SED PCB CONC